X-622-67-435

NASA TM X- 55920

OBSERVATIONS OF SEA SURFACE TEMPERATURES AND OCEAN CURRENTS FROM NIMBUS II

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AUGUST 1967

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Paper presented at the COSPAR TENTH PLENARY MEETING,
July 24-29, 1967, London, England

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OBSERVATIONS OF SEA SURFACE TEMPERATURES AND OCEAN CURRENTS FROM NIMBUS II

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ABSTRACT

Radiometric high resolution infrared measurements recorded by the Nimbus II meteorological satellite in the 3.4 - 4.2 atmospheric window region yielded a complete and detailed global mapping of equivalent blackbody temperatures for a 6 month period. Under clear sky conditions, surface temperatures can be determined within an accuracy of ±1 to 2°K if corrections of 1 to 5°K are applied for residual absorption by atmospheric water vapor and carbon dioxide, depending on the atmospheric composition and scan nadir angle. A good agreement exists between the satellite measurements and sea surface temperature measurements from aircraft and ships.

Of particular interest in this investigation was the usefulness of these infrared measurements for the detection of sea surface temperature discontinuities. During the 174 days of Nimbus II high resolution infrared measurements, the Gulf Stream wall could be seen at least in part in about 50 cases. Other ocean currents such as the Falkland and Brazil Currents, the Agulhas Current and the Kuro Shio could also be detected; and their respective sea surface temperatures were determined.

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INTRODUCTION

The Nimbus II high resolution infrared radiometer (HRIR) was sensitive within the narrow atmospheric window in a spectral range from 3.5 - 4.1 microns. A residual amount of atmospheric absorption by water vapor and carbon dioxide resulted in a drop of measured brightness temperatures by 1 to 3° K for scan nadir angles less than 50 degrees. The expected accuracy of the radiometer was ±1 K. The actual one is slightly less by some residual systems noise. A comparison of the temperatures derived from the radiance measurements by the spacecraft and simultaneous temperature measurements from low flying aircraft indicated a standard deviation of the observed temperature difference by 2.3°K in 288 pairs of concurrent data.

The field of view of the HRIR instrument delineated an area of 8 by 8 kilometers at the subsatellite point, resulting from the aperture of 0.5 degrees and the average Nimbus II altitude of 1100 kilometers. In the chosen spectral range, reflected sunlight is superimposed upon the thermal radiation during daylight conditions. Therefore, brightness temperatures can only be derived from nighttime measurements.

OBSERVATIONS OF THE NORTH WALL OF THE GULF STREAM

During the 174 days of Nimbus II HRIR operation, the Gulf Stream boundary could be detected in significant portions in about 50 cases. Figure 1 is an example where the north wall of the Gulf Stream can be seen under clear sky conditions over a distance of more than a thousand miles. It is a typical example of photo imagery of the radiometric measurements showing data from orbit 1942 on October 8, 1966. The colder land surface appears in a lighter grey than the warmer bay and ocean waters. Extending from Cape Hatteras toward the northeast, a distinct line of temperature contrast can be seen along the meandering Gulf Stream north wall. The cooler coastal waters are represented by a medium grey shade while the warm Gulf Stream water is shown by the darkest tones located between the mentioned colder water and the much lighter grey tones of a large cloud system. The temperatures indicated in Figure 1 are taken from computer-produced grid print maps based on the same data. Figure 2 presents a partial analysis of these numerical data in a Mercator projection. Other grid print maps confirm average temperature gradients along the Gulf Stream boundary of 5 to 10°K over 10 nautical miles which is in good agreement with documented aircraft and ship data. Figure 3 gives an example of four different Gulf Stream boundary locations derived from the satellite data.

An additional interesting detail of figure 1 is the obvious correlation between the Gulf Stream boundary and the northwestern edge of the cloud deck. The synoptic weather chart on October 8, 1966 showed a large anticyclone with continental polar air mass characteristics centered off the Chesapeake Bay. The presented photo facsimile picture indicates a significant sea-air interaction by exhibiting a low-level cloud formation over the warmer ocean waters only. The measured brightness temperatures of the cloud layer suggest cloud top heights of 1000 to 1500 meters. Thus the location, the outlines and the vertical extent of areas of low level instability inside the generally stable anticyclonic regime can be inferred in some detail from these infrared satellite observations, besides the location and intensity of the Gulf Stream north wall.

OBSERVATIONS OF THE FALKLAND AND BRAZIL CURRENT BOUNDARY

A second example may illustrate the world-wide applicability of infrared measurements from satellite for oceanographic purposes Figure 4 is a part of an orbital film strip of Orbit 1248 taken at approximate midnight on August 17, 1966 off the east coast of South America. The Rio de la Plata can easily be identified in the lefthand quarter of the picture. The most pronounced temperature contrast occurs off the coast over the South Atlantic Ocean between the warm Brazil Current and the cold Falkland Current. An interesting detail of the picture is that the Rio de la Plata water, being warmer than the coastal water, seems to be pushed northward along the Uruguay coast instead of flowing straight into the Atlantic Ocean. The width of the zone of strongest horizontal gradient in sea surface temperature along the Brazil and Falkland Current boundary is given in fig. 5 The temperature contrast along this boundary is about 6-8° K. The warmest Brazil Current water is approximately 289 to 290°K in the area between 35 and 40°S. Figure 6 gives an example of an analog trace of a single scan line of the HRIR instrument scanning across the Argentina coast and the Brazil and Falkland Current boundary as well. Disregarding some obvious instrumental noise of high frequency, sections of distinct temperature levels can be recognized in this trace as indicated in the figure. The ocean current boundary is shown as the most pronounced step in signal strength. Rapid changes due to both the horizons as well as inhomogeneities in the cloud system present farther out over the ocean should be disregarded

CONCLUSIONS

These presented results are examples of the great potential which high resolution infrared radiometry from satellite holds for oceanographic research. We have shown that under clear sky conditions sea surface temperatures can be determined and mapped within an accuracy of 1 to 3°K and that the major sea surface temperature discontinuities can be properly located and monitored from a satellite by infrared sensing.

REFERENCES

(1) NIMBUS II USERS' GUIDE, Nimbus Project, Goddard Space Flight Center, Greenbelt, Maryland, July 1966

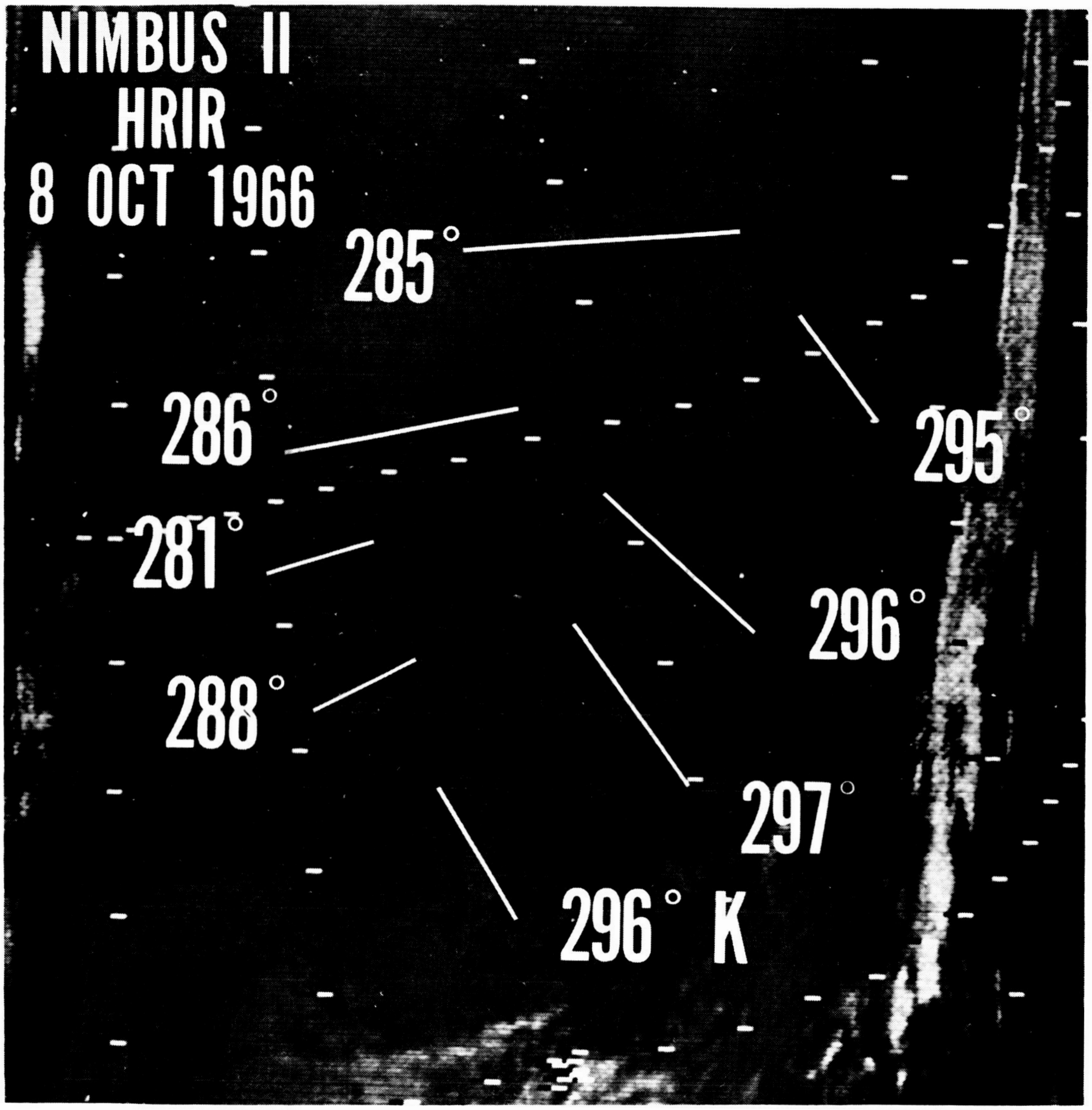

Figure 1. Photo Imagery of Nimbus II High Resolution Infrared Radiometer (HRIR) Measurements During Orbit 1942 on October 8, 1966

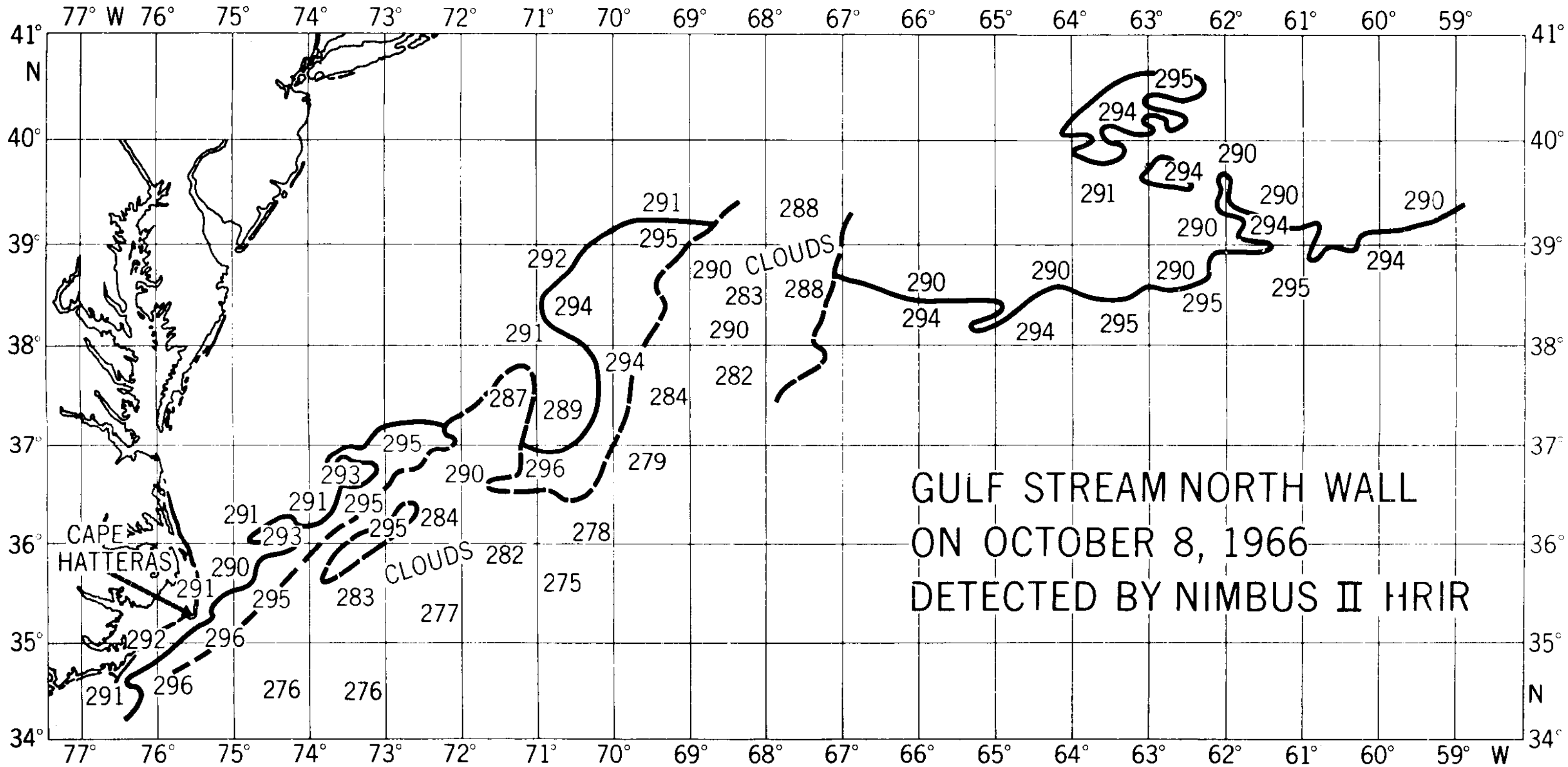

Figure 2. Analysis of Numerical Grid Print Data of Nimbus II HRIR Measurements on October 8, 1966 (Orbit 1942)

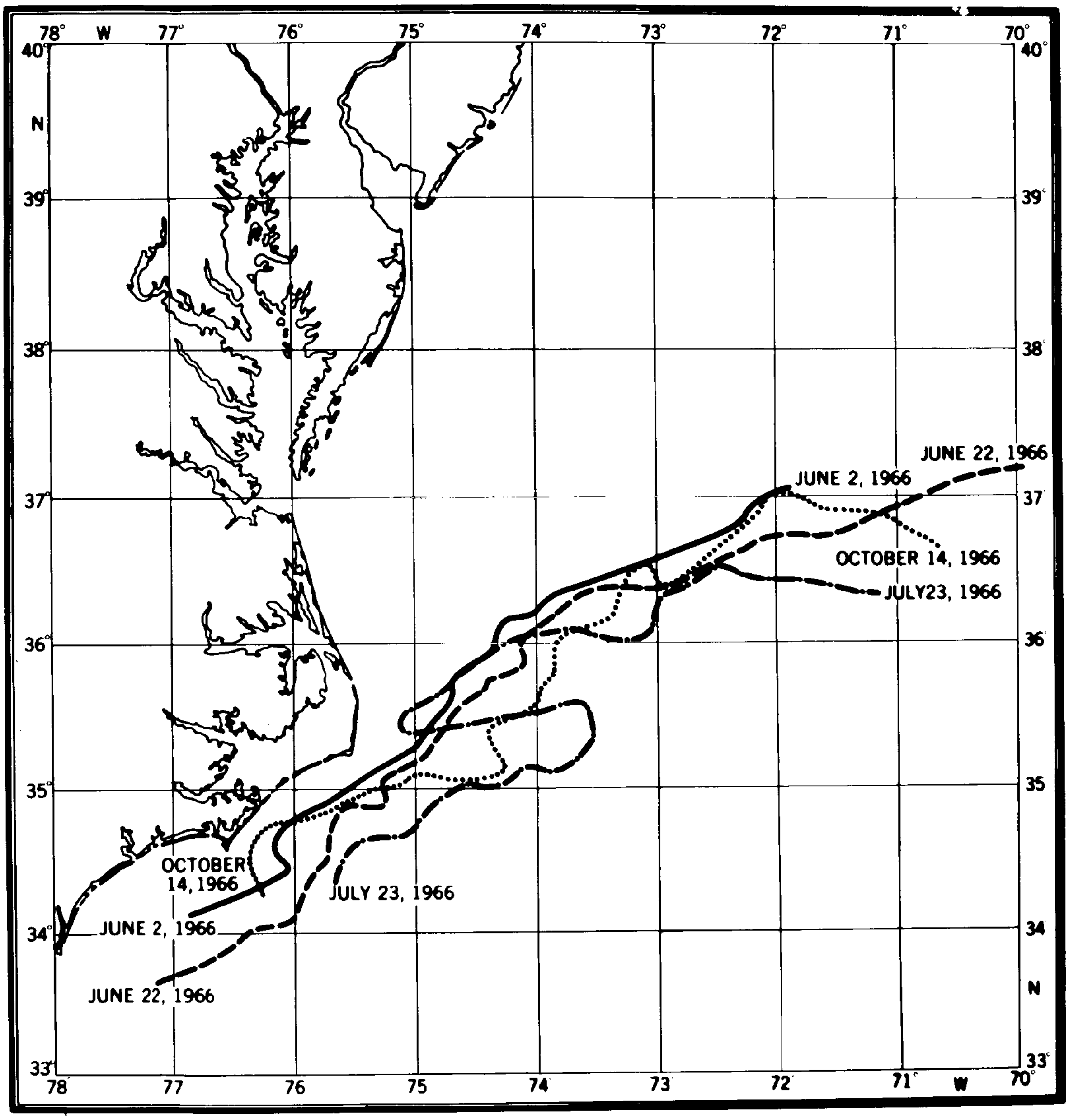

Figure 3. Gulf Stream Boundary Positions Derived from Nimbus II HRIR Measurements from June through October 1966

Figure 4. Photo Imagery of Nimbus II High Resolution Infrared Radiometer (HRIR) Measurements During Orbit 1248 (August 17, 1966)

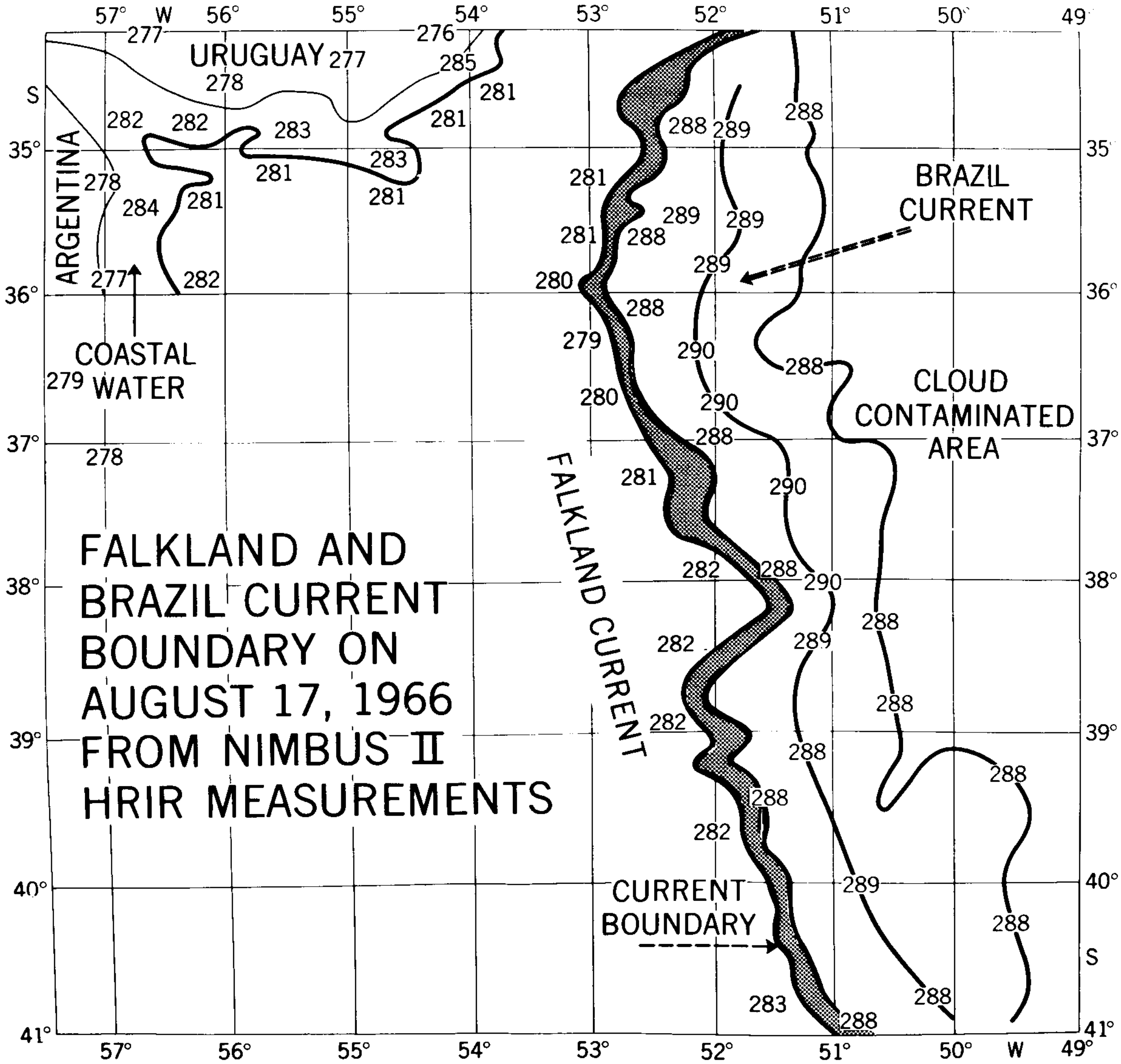

Figure 5. Analysis of Numerical Grid Print Data of Nimbus II HRIR Measurements on August 17, 1966 (Orbit 1248)

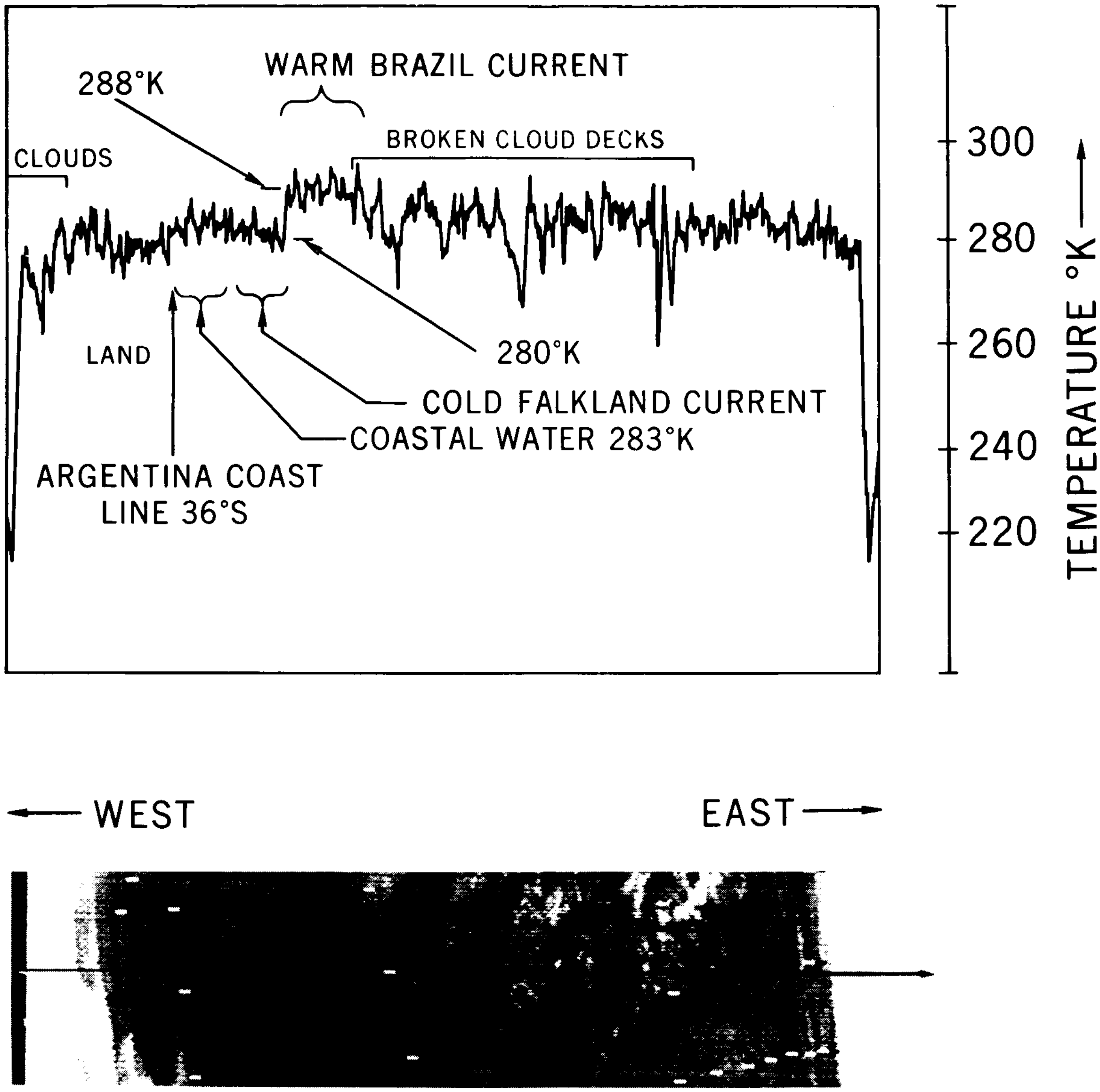

Figure 6. Nimbus II HRIR Analog Record at $02^h 11^m 42^s$ on August 17, 1966 (Orbit 1248)